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Modern Concepts of Cardiovascular Disease

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FROSTBITE

Frostbite is one of the three major types of cold injury, the other two being trench foot and immersion foot. Frostbite is usually defined as that type of cold injury which follows freezing of tissues and thus can occur only when the ambient temperature is below O° C. Trench foot and immersion foot are caused by more prolonged exposure to wetness and less severe cold, and actual freezing of the tissues probably does not occur. In trench foot the wetness is due to wet footwear and in immersion foot to immersion in water, usually the ocean. Cold injuries are primarily of military concern. Their importance to the military is illustrated by the estimate[1] that approximately one-fourth of all the United States casualties in Korea between November 15, 1950 and March 5, 1951 were cases of frostbite. However, sporadic cases of frostbite occur each winter in localities where the temperature drops sufficiently low and, therefore, frostbite is a subject of general interest to physicians and to a large part of the population.

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Pathogenesis

When a limb or other body part is exposed to cold, vasoconstriction normally occurs. The part blanches and may become cyanotic, its skin and muscle temperature fall, and its blood flow is reduced. If the cold exposure is sufficiently severe, this physiological process is intensified, and cooling continues with or without temporary periods of vasodilatation. The part becomes very cold, pale, hard and is frozen. Capillary microscopy and fluorescein studies[2-7] reveal that the circulation stops in the frozen part. When the part is rewarmed, blood flow gradually resumes and may temporarily be increased above normal. The skin becomes hot, red, and edematous, and, although it may remain hot and red for several days, experimental studies show that stasis quickly occurs in the true capillaries and their blood flow stops. This effect apparently is the result of increased capillary permeability allowing filtration of such quantities of plasma that immobile columns of packed red cells remain inside the capillaries. This process has been termed conglutination of red cells and does not represent actual coagulation of blood, for these masses of red cells can be broken up into individual cells which may re-enter the circulation. However, it does seem likely that these conglutinated red cell masses may lead to thrombus formation, and, although heparin does not affect the development of stasis and conglutination, early heparinization is advocated by some workers to prevent secondary intravascular thrombosis.

Histamine or "H substance" has been thought to cause or play a part in these vascular changes[8], but final proof of the role it plays, if any, has not been forthcoming.

If the cold injury is mild, the process will end with mere superficial desquamation of the skin in several days. If the injury has been severe, various-sized bullae usually appear on the hyperemic skin and local edema increases. The bullae are filled with fluid (at first clear, then blood-tinged) which has a protein concentration similar to blood plasma, indicating vascular damage. The bullous fluid tends to clot, and in several days the skin becomes cool, hard, and black, and the part may mummify. The area loses most of its sensation and presents the typical picture of dry gangrene. Microscopic sections at this time[9] show inflammatory exudation, tissue necrosis, and numerous intravascular thrombi. Fibroblastic proliferation occurs in areas near viable tissue.

The relationship of the vascular lesions to the tissues necrosis is not clear. Some workers[5] believe that the vascular lesions result in the tissue necrosis; while others[8,9] feel that both represent evidences of direct cold injury. Nor is it clear what relationship actual ice crystal formation in the tissues and the magnitude of the edema have to the development and extent of tissue necrosis. Skin normally freezes at approximately —1° to —2° C., although under certain conditions "supercooling" will occur, and the skin temperature is reduced much below this level without freezing.

Hematological studies[10] show that the average titer of cold hemagglutinins in the serum of patients who have been frostbitten is slightly higher than in control groups, but it appears

unlikely that cold hemagglutinins play any essential role in the pathogenesis of frostbite. Furthermore, studies of the sickle cell trait[11] have shown that it is not involved in the pathogenesis of frostbite in Negroes.

Clinical Picture

Frostbite usually occurs under some unusual circumstance that results in increased heat loss from the tissues, such as inadequate, lost, or wet clothing, or prolonged exposure from accident, alcoholism, or military exigency. Moreover, cooling of tissues is greatly hastened by wind, the so-called wind chill factor.

The clinical picture varies markedly, depending upon the severity of the injury and the stage at which it is seen. During exposure to the freezing temperature, the patient is usually first aware of coldness, numbness, and tingling of the affected part. This progresses to loss of sensation in the involved area which, if it is an extremity, may become stiff and clumsy. Just as freezing occurs, the patient may experience a momentary sharp pain or "ping", particularly if the skin of the face or ears is affected and if cooling has occurred rapidly.

When thawing occurs and circulation reappears, the patient may experience a burning, throbbing, aching type of pain which generally disappears in a few days. Systemic symptoms vary depending upon the severity of the injury but are usually mild or absent.

Much as with burns, frostbite is conveniently divided into four degrees of severity, although it must be pointed out that the degree of injury is usually not apparent until healing is well advanced, and this may take weeks. The four degrees of frostbite are classified as follows:

First degree — Injury is slight, resulting in erythema with or without slight edema. These manifestations disappear in a few hours, and superficial desquamation of the skin occurs in several days.

Second degree — Injury to the skin is superficial to the stratum germinativum. Following rewarming, erythema and edema are more marked and longer lasting than in first degree frostbite, and vesicles and bullae appear within twenty-four hours. The latter burst, or their contents are gradually reabsorbed, and the skin becomes dry, hardens, and darkens, resulting in a black eschar. The latter peels off in several weeks leaving new skin beneath.

Third degree — The full thickness of the skin and varying amounts of the subcutaneous tissue are involved. The involved skin forms a black eschar with or without previous bulla formation, and, when finally shed, leaves an ulcerated area which must heal by secondary intention. Infections or failure to heal may require surgical debridement or even amputation.

Fourth degree — Damage involves full thickness of the part, including bone, and subsequent loss of tissue is inevitable.

When second, third, or fourth degree frostbite has occurred, the lesser degrees of injury are usually present in the more proximal portions of the same extremity. For example, in frostbite of the foot the distal one-half of the foot may be covered by a heavy black eschar. Most of this may be due to secondary injury, and the eschar over this part will eventually peel away and leave new skin. Some of the proximal portions of the toes may be ulcerated by third degree frostbite, and only the distal phalanx of one or more toes may be lost. As it is extremely difficult or impossible to assess correctly the degree and extent of injury early in its course and often for many weeks afterward, it is imperative that the utmost conservatism be employed in handling frostbite. Surgical amputation should be postponed until a clear line of demarcation extending down to the bone appears, for, as indicated above, frostbite differs from the usual peripheral vascular disease where gangrene of the skin generally signifies gangrene of the underlying tissues. Early amputation will result in the needless loss of much viable tissue, and, although healing is slow, the extent of recovery is usually gratifying and surprisingly complete.

Healing of necrotic lesions of digits may result in mild acrosclerosis, as manifested by tightly-stretched, smooth skin that fails to wrinkle, atrophy of subcutaneous tissue, and deformity of nail beds. During and following healing, disturbances of the autonomic nervous system may appear, such as hyperhidrosis, vasospasm, and mottling of the skin. These disturbances are usually transitory and of no great importance. Chronic pain and recurrent ulceration are rare. Once injured by cold, a part is assumed to be more susceptible to cold injury thereafter. However, since there are few long-term follow-up studies of frostbite, more studies are needed definitely to establish this and other points.

An interesting x-ray follow-up study[12] of soldiers recovering from frostbite of hands and feet has shown a surprisingly high incidence of x-ray changes. Transient osteoporosis was present in many cases, and mutilation of bone which had been exposed to air by ulceration was also observed. In a small group of patients, defects occurred close to joints of hands and feet, often in digits that had not shown clinical evidence of frostbite. This last type of roentgenological

ANNUAL MEETING OF THE AHA, 1954

The Annual Meeting of the American Heart Association in 1954 will be held at the Conrad Hilton Hotel in **Chicago.** The Assembly Panels and the General Assembly will be held on Thursday and Friday, April 1 and 2, and will be followed by a specific scientific program on clinical cardiology on Saturday and Sunday, April 3 and 4, conducted under the auspices of the newly formed Section on Clinical Cardiology of the Scientific Council. These sessions will immediately precede the annual meeting of the American College of Physicians.

SCIENTIFIC PROGRAM OF THE SECTION ON CLINICAL CARDIOLOGY, 1954

The Section on Clinical Cardiology of the American Heart Association will sponsor a two-day scientific program at the Conrad Hilton Hotel in Chicago on April 3 and 4, 1954. This program will constitute a portion of the Annual Meeting of the American Heart Association and immediately precedes the Annual Sessions of the American College of Physicians. The meeting will be open to all members of the medical profession. Doctor Wright R. Adams of Chicago is Chairman of the Program Committee. Members of the American Heart Association who wish to present papers should send a 250-300 word abstract of the proposed paper to Doctor Charles D. Marple, Medical Director, American Heart Association, Inc., 44 East 23rd Street, New York 10, New York. *All papers should be on subjects of distinct clinical interest. The deadline for the receipt of abstracts is January 1, 1954.*

Remember — the only official journals of the American Heart Association are

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ANNUAL SCIENTIFIC SESSIONS, 1954, and THE SECOND WORLD CONGRESS OF CARDIOLOGY

The Second World Congress of Cardiology and the 27th Scientific Sessions of the American Heart Association will be held jointly in Washington, D. C., September 12-17, 1954. Membership in the Congress will be open to all members of the American Heart Association; nonmembers may attend by special invitation of the Organization Committee.

American and Canadian scientists desiring to present papers should submit titles with abstracts of not over 200 words, typewritten, double-spaced, in duplicate. They should be addressed to Charles D. Marple, M.D., Medical Director, American Heart Association, 44 East 23rd Street, New York 10, N. Y., and *must be received on or before April 1, 1954.*

The Formal Announcement of the combined meeting will be distributed widely to the medical profession within the month. For further information, address Dr. L. W. Gorham, Secretary-General, Second World Congress of Cardiology, 44 East 23rd Street, New York 10, N. Y.

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change generally became evident about eight months after freezing and usually consisted of defects of the joint edges.

Frostbite occurs most often in the extremities, and the great toe is the part most frequently damaged in ground-type frostbite. This is illustrated by an analysis[13] of 1,880 cases of frostbite suffered by United States ground troops in Korea who were subsequently evacuated to Japan. Eighty-six per cent had frostbite of the feet only, and in a large majority of these injury was limited to the great toes. In 11 per cent of the 1,880 soldiers, hands and feet were involved; in 2.5 per cent, hands only; and in a small group of 0.5 per cent, other parts including ears, face and knees were frostbitten. In the same group of 1,880 soldiers, first degree frostbite was the most severe lesion in 17 per cent, second degree in 34 per cent, third degree in 44 per cent, and fourth degree in 6 per cent.

Treatment

Clinical evaluation of various methods of therapy is greatly complicated by the difficulty in correctly assessing the degree and extent of injury when the patient is first seen. Because of this difficulty and the fact that a large number of patients are seldom seen except under battle conditions where carefully controlled studies are seldom possible, many studies have been made of the effects of various drugs and procedures on the course of experimental frostbite in animals. Most of these studies, however, suffer from the fact that experimental frostbite in animals is usually produced by a brief exposure to intense cold, while most clinical frostbite is produced by more prolonged exposure to less intense cold, and is often complicated by fatigue, hunger, alcoholism, etc. Consequently, results obtained in experimental frostbite in animals must be cautiously applied to clinical frostbite.

Rewarming. It is comparatively seldom that a physician sees a patient while an extremity or other part is still frozen, and custom has it that a frostbitten area should be rewarmed slowly, perhaps in snow, and with much massaging. Recent experimental work[9,14,15] has demonstrated, however, that tissue necrosis is significantly less following quick-freeze injuries in animals if the frozen part is rapidly rewarmed. As yet it has not been determined whether clinical frostbite will also respond favorably to rapid rewarming, and a careful clinical evaluation of the effects of rapid rewarming is badly needed. Rewarming is best accomplished by immersing the frozen part for several minutes in water heated to 42° C. (108° F.). Care must be exercised in doing this, however, for water heated to 50° C. increases the tissue damage. Warm water is used in preference to warm air, as the latter is such a poor conductor of heat that rewarming may actually be accomplished faster in cool water than warm air. In the absence of warm water, a warm hand or other source of heat may be placed on the frozen part, but local massage should be strictly avoided as this only increases the tissue damage. Once thawing has occurred and the part is rewarmed to a normal body temperature, external sources of heat should be withdrawn.

Local Care. Proper local care of frostbite does much to preserve tissue and function. The injured part should be left exposed to air at normal room temperature, and bullae should be allowed to reabsorb spontaneously. All trauma to the injured area must be carefully avoided, and this can usually be best accomplished by putting the patient to bed, at least initially, with the bed clothing folded back above the ankles when the feet are involved. Vaseline or other greasy bandages are to be strictly avoided, as they only lead to maceration, infection, and increased tissue loss. Plaster casts and pressure dressings have been tried without uniform success[6,15] and are not recommended. Physiotherapy is important as healing progresses.

Antibiotics. The army has followed the policy in Korea[1] of giving a booster injection of tetanus toxoid and daily prophylactic penicillin injections to all frostbite patients. This would seem to be a wise course particularly if ulceration has occurred. Local infection does commonly occur, and this can be treated with appropriate antibiotics, dilute zephiran soaks, and superficial debridement of necrotic tissue as required. It is rare that local infection (wet gangrene) forces early amputation.

Anticoagulants. As with rewarming, there is no adequate clinical evidence on which to base an opinion as to the efficacy of anticoagulants in reducing the extent of tissue necrosis following cold injury. Nor is there agreement as to their effect in experimental frostbite, except that they must be started soon after injury if any beneficial effects are to follow. Yet, reserving final judgment as to its efficacy until more definitive studies have been made, it seems reasonable at this time to begin heparinization of patients who have probably experienced severe injury, if they are seen within twelve to twenty-four hours after rewarming, and if there are no other conditions present contraindicating anticoagulants. Heparin should be given in such doses as needed to maintain a continuous uninterrupted prolongation of the blood clotting time to approximately thirty minutes for five to seven days.

As yet, there are few reports on the treatment of frostbite with dicumarol or other long-lasting anticoagulants.

Vasodilators. Vasodilator drugs, such as hexamethonium and priscoline, regional sympathetic blocks, and sympathectomies have been used in an effort to increase the blood supply to a frostbitten part. To date, there has not been sufficient experience to evaluate their effect properly, and their use must still be considered experimental especially in the acute stages. It seems likely that they will be found most useful in patients who display signs of sympathetic overactivity during recovery.

Smoking is usually discouraged in third and fourth degree frostbite in an effort to avoid all vasoconstrictor agents.

Other Drugs. Cortisone and ACTH have been used and found ineffective in the treatment of both experimental and clinical frostbite[1,9,15]. Consequently their use is not recommended.

Rutin and antihistaminics have shown some promise in the treatment of experimental frostbite[15,16], but they have not been evaluated clinically. Rutin is used in an effort to decrease capillary permeability, and the antihistaminics are used for their neutralizing effect on the supposed histamine-like substance.

Intravenous procaine was used extensively by the army in the treatment of frostbite casualties in Korea during the winter of 1950-1951[1]. Its only beneficial action, however, seems to be its analgesic effect, and its use is not recommended. If analgesia is required, the usual analgesic drugs are safer, more efficacious, and easier to administer.

Surgery. Except in the rare instances of wet gangrene not controlled by antibiotics or other complication surgical amputation should not be undertaken until a definite line of demarcation between necrotic and viable tissue has appeared. Amputation may be performed close to the line of demarcation with satisfactory healing. This line of demarcation should preferably extend down to bone. It must be emphasized again that the development of a line of demarcation may take many weeks and that the development of a black eschar is no indication for amputation. A black eschar does not necessarily denote any more than second degree frostbite and may peel off and leave healthy new skin beneath. At times, it seems wise to "bivalve" a heavy black eschar encasing a digit in an attempt to increase its blood supply.

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The opinions and conclusions expressed herein are those of the author and do not necessarily represent the official views of the Scientific Council of the American Heart Association.